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High Energy Theory Group

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Research Activities

(I) Does Accidental Degeneracy Imply a Symmetry Group ?[1)] (H. Ui and G. Takeda)

The question whether an accidental degeneracy in quantum mechanical system always implies the internal symmetry group of the system is probed by means of the simple model of the three-dimensional harmonic oscillator with a constant spin-orbit potential: $H=(1/2)(p^2+r^2)+\lambda\sigma\cdot L$. For the fixed values of $\lambda\mp 1$, this model has an interesting degeneracy of remarkable regularity; in particular, the ground state is infinitely degenerate, consisting of all the nodeless $j=l\pm 1/2$ states. In order to systematically seek the symmetry group, we first investigate the full dynamical group of the system. To our surprise, we find that the dynamical group of our system for an arbitrary value of λ is the graded Sp(6R) - a supergroup extension of the dynamical group Sp(6R) of the three-dimensional harmonic oscillator. We find the graded SU(3) as its subgroup, which is a supergroup extension of the well-known symmetry group SU(3) of the harmonic oscillator. It is further shown that there exists a natural group chain, $grSp(6R)\supset Sp(2R)\times grO(3)$, which corresponds to the group chain $Sp(6R)\supset Sp(2R)\times O(3)$, where $\times$ denotes the direct-product. Next, we examine whether any subgroup of the full dynamical group constitutes the symmetry group of the system responsible for the accidental degeneracy. It is shown that there is no such a symmetry group in the system and that, instead of the symmetry group, there exists a special, simple algebraic structure which is essentially responsible for the accidental degeneracy.

(II) Superspace Lagrangian Model of Supersymmetric Quantum Mechanics in Three-Dimensional Space (G. Takeda and H. Ui)

By employing the superspace formalism, we construct a model of supersymmetric quantum mechanics in the three-dimensional space. Our model can be viewed - in the context of nonrelativistic quantum mechanics - as describing the motion of a spinning particle in central and one-body tensor potentials, both of which are determined by a single superpotential. As an example, we examine the simplest model obtained by taking the harmonic superpotential. It is shown that the supersymmetry is an exact symmetry of this model and that the model possesses the supergroup SU(3/3) as its maximal symmetry group. More general case of the polynomial superpotential is discussed. It is proved that the supersymmetry cannot be spontaneously broken for any polynomial superpotential in our three-dimensional supersymmetric quantum mechanical system.

(III) Algebraic Approach to Chiral Anomalies: General Solution of the Consistency Condition (K. Itabashi)

General form of nontrivial solutions of the Wess-Zumino consistency condition is derived, and the uniqueness of the chiral anomalies is discussed. Whole of the argument is based on the algebraic treatment of the problem in the extended Euclidean space-time of the dimension higher than six. Particularly crucial to the argument is a lemma, the proof of which is presented in detail.

(IV) The Abelian-Flux Model and Quark-Confinement (T. Akiba)

We present a simple phenomenological description of quark-confinement based on the abelian-flux model. Both heavy quarkonia and light-quark hadrons are treated in a unified way. Fits to Martin's heavy-quark potential and to the experimental value of the string tension yield reasonable values to the bag constant or the quark-gluon coupling constant. As for light-quark baryons the model leads to a bag-picture of baryons in conformity with the cloudy chiral bag model.

(V) New Formulation of Constituent Quark Model for Projectile Fragmentation in Hadron-Hadron and Hadron-Nucleus Collisions[2] (F. Takagi)

Mulliple production of hadrons at high energies is dominated by soft interactions. Hence, it cannot be described by the established perturbative QCD (quantum chromodynamics) alone. An appropriate phenomenological model is necessary. The constituent quark model (CQM) is one of the most successful models in describing hadron-hadron, hadron-nucleus and possibly nucleus-nucleus collisions. However, results from some latest experiments on inclusive reactions such as $\pi^{\pm}+p\to p$ or $\bar{p}$ + anything, $\pi^{\pm}+A\to p, \bar{p}, \Lambda$ or $\bar{\Lambda}$ + anything, $p+p\to\Lambda$ or Δ^{++} + anything and $\bar{p}+p\to\bar{\Lambda}$ or $\overline{\Delta^{++}}$ + anything exhibit such surprising features that most models including CQM might be ruled out. We propose how to improve the CQM in order to preserve its validity. The main ingredients are quark-antiquark annihilation, quark flavour content in the central region and quark shadowing effect.

(VI) Power-Spectrum Analysis of Fluctuations of Pseudorapidity Distributions in Nucleus-Nucleus Collisions at Very High Energies[3)] (F. Takagi)

Two events of ultrarelativistic nucleus-nucleus collisions observed in the Japanese-American cooperative emulsion experiment show large fluctuations of the pseudorapidity distributions of the charged secondaries. The fluctuations are analyzed by use of the power spectrum. A simulation is used to estimate the statistical noise. Fairly strong signals are found in the Si-AgBr event, while the Ca-C event exhibits only weak signals.

(VII) SU(4)×SU(2) Unification in Kaluza-Klein Supergravity[6)-8)] (Z.F. Ezawa, I.G. Koh and S. Rajpoot)

We consider partial unification of Pati-Salam type based on the isometry group SU(4)×SU(2). This isometry arises from the compactification of the eleven-dimensional supergravity into $M^4 \times S^5 \times S^2$, and branches into SU(3)×SU(2)×U(1) subsequently. Their coupling constants and evolutions are studied by using one-loop renormalization group equations. However, the absence of quark-lepton representations in the harmonic expansion and the classical instability of the manifold are still unsolved problems.

(VIII) Monopole-Induced Baryon Decay with Arbitrary Number of Generations and Effects of Fermion Mass[9)] (Z.F. Ezawa)

Baryon number condensation around a monopole is estimated in the presence of N fermion generations. The massless fermion model is studied for arbitrary N, while the massive fermion model is analyzed in the large N limit. It is shown that in these cases ($N>1$) the chiral anomaly does not contribute to baryon decay.

(IX) Abelian and Non-Abelian Anomalies in Monopole-Fermion Interactions (Z.F. Ezawa)

According to the standard procedure the monopole-fermion system is reduced to an effective two-dimensional model. This is a generalized Schwinger model containing four Abelian gauge fields interacting with N generations of massless fermions through vector and axialvector couplings. We quantize such a system exactly in the cannonical operator formalism.

Then, analyzing the cluster property of operators carrying various chiral charges, the roles of the Abelian and non-Abelian anomalies are studied in monopole-induced baryon decay. The vacuum angle is shown to appear in association with the Abelian anomaly. We also discuss in detail what is the driving force of baryon decay. Although the classical conservation laws suggest the importance of the weak field, we demonstrate that this is not the case by performing a dynamical calculation in quantized theory.

(X) Functional-Integral Approach to Chiral Anomalies in Supersymmetric Gauge Theories (K. Konishi and K. Shizuya)

We formulate anomalous chiral and related Ward-Takahashi identities in supersymmetric gauge theories, by generalizing Fujikawa's functional-integral method to superspace. Our approach provides a manifestly supersymmetric and gauge covariant treatment of the superspace Abelian anomalies, and is applicable to chiral- as well as to left-right symmetric theories. Non-Abelian anomalies are also discussed briefly.

Superspace Abelian anomalies imply that particular composite operators, i.e., those containing the associated U(1) currents as a component, exhibit an anomalous supermultiplet structure. We discuss how this leads to various exact relations among scalar and gauge-fermion condensates, thereby imposing strong constraints on possible chiral-symmetry realizations in supersymmetric confining theories.

(XI) Composite Quarks and Leptons[10] (W. Buchmüller, R.D. Peccei and T. Yanagida)

We consider a model of quarks and leptons as quasi-Nambu-Goldstone fermions which is based on an underlying supersymmetric $SU(2)\times SU(2)$ preon theory. The spontaneous breakdown of a global $U(6)\times U(6)$ symmetry to $U(4)\times U(4)\times SU(2)$ creates both quarks and leptons and at the same time allows for the possibility of having either residual or fundamental weak interactions.

(XII) Weak Bosons as Composite Gauge Fields[12),13)] (T. Kugo, S. Uehara and T. Yanagida)

We find a hidden local symmetry in the supersymmetric $U(4n+2)/U(4n)\times SU(2)$ non-linear sigma model which was proposed recently as a phenomenological model based on an SU(2) preon theory (Buchmüller, Peccei, Yanagida). The hidden symmetry is identifiable with the standard Weinberg-Salam gauge symmetry and hence we suggest that the weak intermediate bosons discovered at CERN are dynamical gauge fields of the hidden symmetry.

(XIII) The Galaxy Formation by Massive Unstable Neutrinos[11)] (M. Fukugita and T. Yanagida)

A lower bound is derived on the mass of muon neutrino, $m_{\nu_\mu} \gtrsim 0$ (1 KeV), by a combined use of a variety of neutrino mass experiments. Consistency with the cosmological mass density implies the presence of a flavour changing neutrino current with a symmetry breaking parameter v smaller than 10^{11} GeV. Further consistency with the galaxy formation sets the parameters to be in a very narrow range near $m_{\nu_\mu} \sim 1$ KeV and $v \sim 10^{10}$ GeV, for which the visible mass of galaxies that can be reached is order $\sim 10^{9}-10^{11}$ M .

(XIV) Gravitational Instability in the Higher-Derivative Kaluza-Klein Theory[14)]
(W. Ishizuka and Y. Kikuchi)

We study the one-loop effective potential in the higher-derivative theory. The similar instability found by Appelquist and Chodos emerges in a simple Kaluza-Klein model.

(XV) The Kähler Potential of $E_6/Spin(10)\times SO(2)$[15)] (Y. Yasui)

We calculate the E_6 invariant Kähler potential of $E_6/Spin(10)\times SO(2)$ using the Jordan algebra. We find that this manifold is imbedded into CP(26).

(XVI) Gravitational Instability and Curvature Effect at Finite-Temperature[16)]
(Y. Kikuchi, T. Moriya and H. Tsukahara)

We investigate the gravitational instability which is indicated by the appearence of an imaginary mass proportional to the squared temperature. We show in the perturbative calculations that the time component of the graviton's self-energy $\Pi_{00,00}$, which was calculated by Gross, Perry and Yaffe, depends on the definitions of the graviton field while $\Pi_{00,00}-\Pi^{\mu}{}_{\mu,00}$ does not depend on them. However its value is found to differ from the one in the classical argument by a factor 3/2. The effect of space-time curvature on this instability is qualitatively studied.

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Doctor Thesis (March 1985)

1) Field Theories in the Random External Field, Wataru Ishizuka.

Master Thesis (March 1985)

1) Massive Neutrinos and Their Properties, Mizuhiko Hosokawa.
2) Anomalies in Renormalization, Motohiro Kanda.